THE WEATHER AND CIRCULATION OF MARCH 1960

A Cold, Snowy Month

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1. HIGHLIGHTS

Cold and snowy weather prevailed in the eastern two-thirds of the United States during March 1960, while temperatures in most of the remaining (western) portions were warmer than normal. Many of the eastern stations reported the coldest March of record, and in some places the monthly mean temperature was as much as 6° or 7° F. colder than the previous record low.

This prolonged wintry weather was associated with blocking in North America, which originated during the winter [10] and continued to dominate the circulation throughout most of March 1960. This block was so tenacious and widespread that the index of 5-day mean zonal westerlies for the temperate zone (35° N.–55° N.) averaged over the Western Hemisphere was continuously below normal from January 7–11, 1960 to March 19–23, 1960.

2. MEAN CIRCULATION

The monthly mean circulation at 700 mb. for March 1960 in the United States consisted of a ridge over the Plateau States and a pronounced trough along the east coast with an anomalous, northerly flow in between (fig. 1). The trough was associated with equatorward-displaced westerlies and cyclonic activity south of the blocking ridge centered over the Ungava Peninsula in eastern Canada. This ridge was abnormally cold and consequently not very impressive at the 700-mb. level where heights averaged only 160 feet above normal.

Blocking was also evident in other areas. High-latitude anticyclones with major positive anomalies were located in northeastern Siberia and in Scandinavia. In the eastern Atlantic the normal seat of cyclonic activity was displaced southward (note −350-ft. anomaly in fig. 1), and many storms were deflected by the blocking High into southern Europe. East of the Scandinavian High a much stronger than normal northerly flow produced unusually cold weather in central Eurasia.

A Gulf of Alaska Low appeared in the mean in March after being absent in January and February 1960. It was the southeastern component of the typical "omega" block in this region.

These 700-mb. centers of action also appeared on the sea level 30-day mean (fig. 2). As expected, the cold North American block was more prominent at the lower level; above normal pressures were observed over most of Canada and the United States, with a ridge extending from the Yukon to Florida. This sea level map is typical of those associated with cold regimes in eastern United States. In fact, the sea level mean for this March is similar to the one for March 1915 when many previous temperature records were established.

3. CHANGE IN MEAN CIRCULATION FROM FEBRUARY TO MARCH 1960

The major change in the mean circulation at 700 mb. from February to March was the diminution of blocking and above normal heights over Greenland and eastern Canada (fig. 3). The maximum anomalous height fall (−660 ft.) was centered over southern Greenland, but 700-mb. heights also fell over practically all areas of Canada. In the United States rises in the west combined with falls in the east to intensify the northwesterly flow in the eastern portion of the country. This resulted in a marked cooling in New England where monthly mean temperatures were actually colder in March than in February.

The intensity and evolution of the North American blocking is well illustrated by a time series of 5-day mean 700-mb. height anomalies which are two weeks apart (fig. 4). Heights were far above normal in eastern Canada during the middle of February. They fell slowly thereafter but were still 550 ft. above normal by mid-March. Subsequently, this blocking weakened and heights dropped to approximately 500 ft. below normal by the end of the month.

While the positive anomalies existed in eastern Canada, heights were subnormal to the south over the United States in a fashion quite typical of blocking. As the blocking relaxed, in late March, 700-mb. 5-day mean heights over eastern United States increased to above normal values for the first time since early February.

A simple index was computed to indicate further the persistence, early period strength, and gradual decline of blocking in eastern North America. This blocking index (fig. 5) was obtained by subtracting the 700-mb. 5-day mean height departures from normal averaged over a small area (10° square) centered at 35° N., 65° W. from

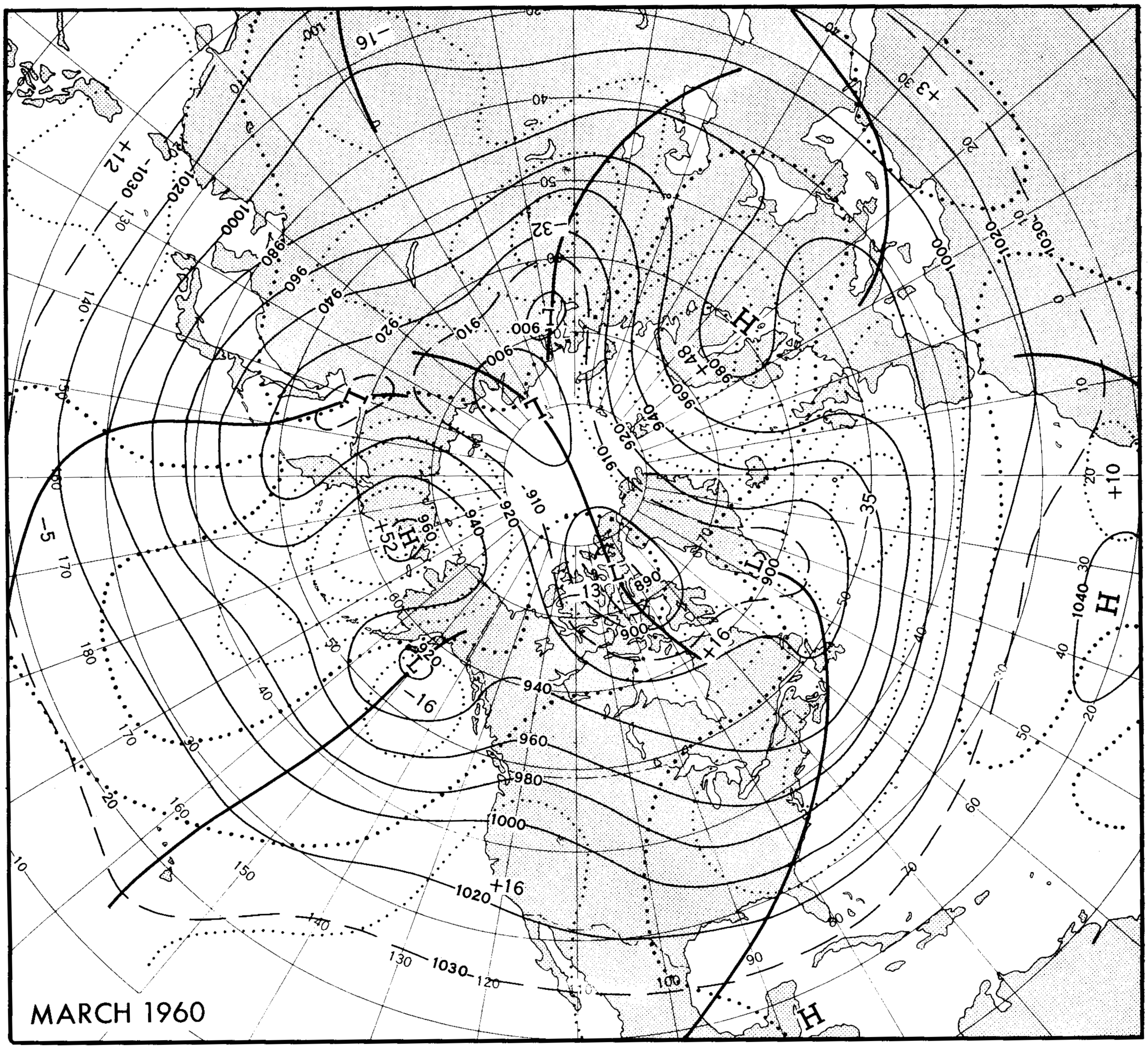

FIGURE 1.—Mean 700-mb. contours (solid) and height departures from normal (dotted), both in tens of feet, for March 1960. Blocking was prevalent this March.

a similar spatially averaged center at 60° N., 65° W. If height anomalies were more positive or less negative in the northern than in the southern area, this blocking index would be positive. A positive value also means, of course, that the westerlies were weaker than normal in this small longitudinal sector. Values were computed three times per week.

The blocking index was largest early in the period and continuously positive until the March 22–26, 1960 period. The decrease in blocking was gradual with only minor oscillations.

While blocking remained in eastern North America, surges of rising heights at high latitudes and falling heights at low latitudes migrated simultaneously westward, in a fashion referred to as a blocking surge by Namias [6]. By the first of March, 700-mb. heights were above normal in high latitudes from Greenland westward to eastern Siberia and generally subnormal in middle latitudes from Great Britain to the central Pacific (fig. 4). This regime changed slowly so that by the end of March the anomaly pattern had almost completely reversed with subnormal and

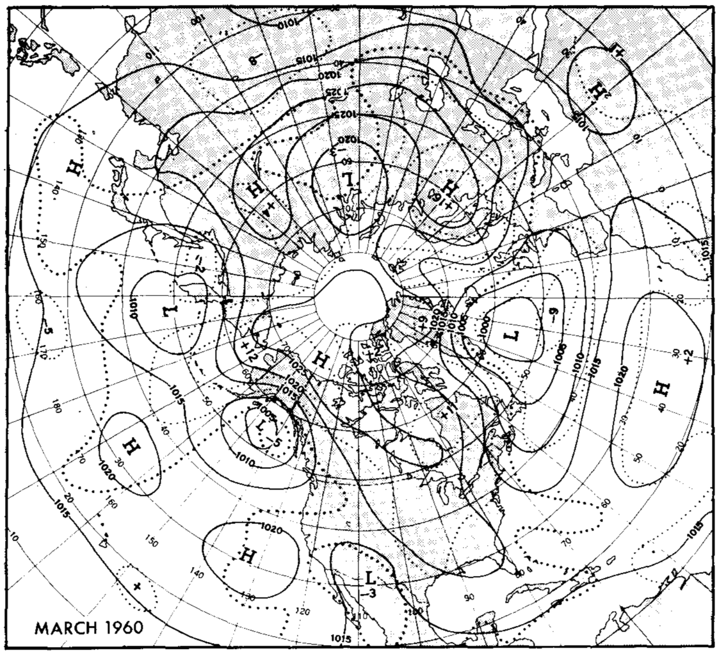

FIGURE 2.—Mean sea level isobars (solid) and pressure departure from normal (dotted), both in millibars, for March 1960. Isoline interval of anomalies is 4 mb. Pressure was above normal over most of North America.

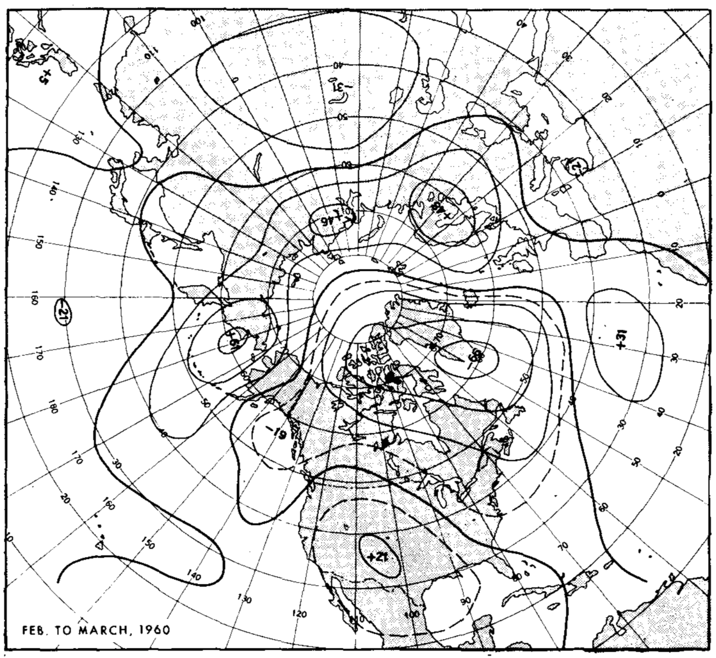

FIGURE 3.—Difference between monthly mean 700-mb. height anomaly for February and March 1960 (March minus February) in tens of feet. There were large height falls over eastern Canada and northeastern United States.

supernormal heights found in high and low latitudes, respectively.

4. WEATHER OVER THE UNITED STATES

PRECIPITATION

The pattern of total precipitation for March 1960 over the United States was quite complicated with essentially three small-scale patches of supernormal precipitation (fig. 6). In the Northwest the mid-tropospheric winds (fig. 1) were stronger than normal from the southwest, a factor which enhanced the orographic precipitation. Furthermore, there was some cyclonic activity in this area (Chart X in [12] and fig. 2). This precipitation was uniformly distributed throughout the month [13].

In the Southeast the circulation was also favorable for heavy rainfall. This region was near the mean trough, and depressed jet stream (fig. 1), near one of the preferred storm tracks (Chart X in [12]), and also in the area of frequent fronts (fig. 7). Here the precipitation was heavier than in any other part of the United States (fig. 6), and record amounts for March were reported in Florida. The bulk of this record rainfall occurred during the third week of March in connection with severe local weather along a stationary front (No. 12 in [13]).

Heavy precipitation over the central Great Plains and moderate precipitation in other regions east of the Rocky Mountains resulted indirectly from the blocking regime and the attendant cold mass of air which persisted over the eastern half of the United States. Several cyclones formed in the Southwest and Gulf of Mexico and moved slowly eastward or northeastward (Chart X in [12]). Overrunning of the obstructing cold airmass in front of these perturbations produced severe snowstorms from the Rocky Mountains to the east coast. The areas which experienced major snowstorms can be roughly determined by inspection of table 1 which lists various snowfall records that were made this March. Further information and descriptions of the snowstorms of March 1960 appear in [13], and in [4] there is an interesting discussion of the March 3–5, 1960 storm. This "northeaster," embedded in the blocking regime of early March, decelerated as it moved northward along the east coast of the United States and produced a great snowstorm in southeastern New England.

TABLE 1.—*Total snowfall for March 1960 at selected cities that received the largest amount for any March on record*

Station	Snowfall (in.)	Station	Snowfall (in.)
St. Joseph, Mo	23.1	Harrisburg, Pa	22.6
Columbia, Mo	24.5	Roanoke, Va	*30.3
Cairo, Ill	20.3	Richmond, Va	19.7
South Bend, Ind	33.9	Asheville, N.C	*28.9
Evansville, Ind	20.2	Cape Hatteras, N.C	8.5
Louisville, Ky	22.9	Charlotte, N.C	19.3
Lexington, Ky	17.7	Greensboro, N.C	*21.3
Knoxville, Tenn	20.2	Greenville, S.C	15.3
Akron, Ohio	20.9	Atlanta, Ga	4.8
Youngstown, Ohio	20.6	Rome, Ga	8.3
Pittsburgh, Pa	21.3		

*Record for any month.

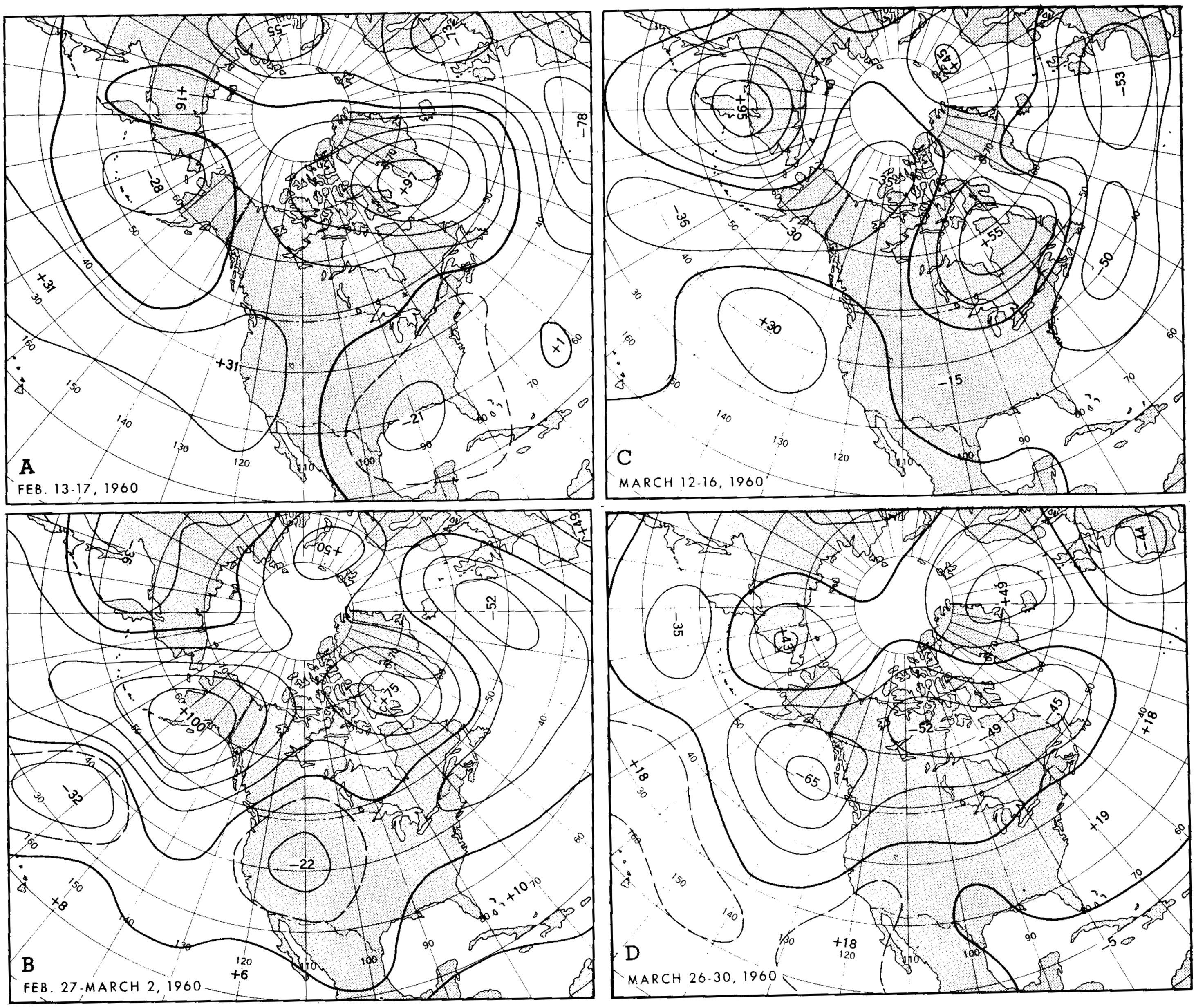

FIGURE 4.—Five-day mean 700-mb. height departures from monthly normal in tens of feet for indicated periods (2 weeks apart) in February and March 1960. Blocking surge [6] was significant evolution of circulation.

In the remainder of the country precipitation was subnormal under the influence of dry, northerly flow between the trough in the east and ridge in the west (fig. 1), a pattern favorable for dry weather.

PERIODICITY

Periodic recurrences in the weather have been noted by several investigators [1, 2, 7]. As pointed out by Namias [7], periodicities frequently occur in spring and also are probably most apparent during periods of persistent or slowly changing general circulations, such as existed this March. During such periods several storms frequently pursue the same general track. This March both layman and meteorologist in Washington, D.C., commented on the fact that storms were affecting the area every Thursday. A plot against time of the total precipitation for each day (fig. 8) shows an approximately 7-day periodicity in February which maintained remarkably well throughout most of March. It is interesting to note that a trace was reported on March 24, the expected time for precipitation if the cycle had continued, even though marked changes in the mean circulation had occurred by this time.

TEMPERATURE

The outstanding weather feature of March 1960 was the extreme and tenacious cold over a large area of the eastern United States. The March mean temperatures were the lowest on record this year at a great many stations (fig. 9).

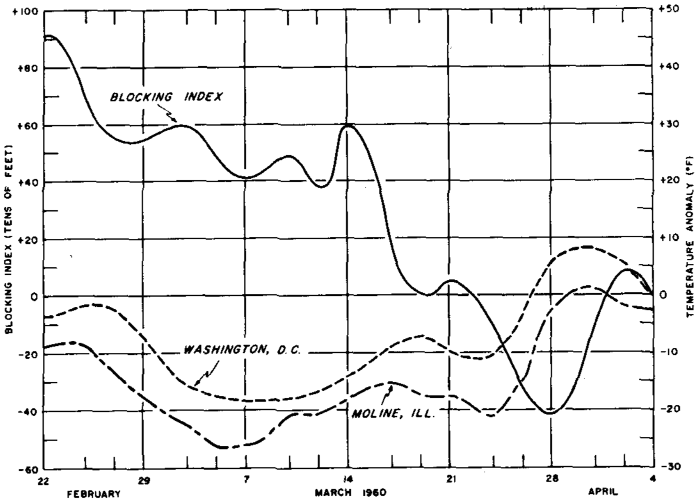

FIGURE 5.—Time variation of the 5-day mean temperature anomaly (° F.) at Moline, Ill., and Washington, D.C., and the blocking index for February and March 1960. Blocking index is obtained by subtracting the average of the four 5-day mean height anomalies at 40°N., 60°W.; 40°N., 70°W.; 30°N., 60°W.; 30°N., 70°W. from the average of the four at 65°N., 55°W.; 65°N., 75°W.; 55°N., 55°W.; 55°N., 75°W. Large positive value indicates strong blocking. Both blocking and temperature values were computed for all available 5-day mean periods, three per week, and plotted opposite the middle day of the periods.

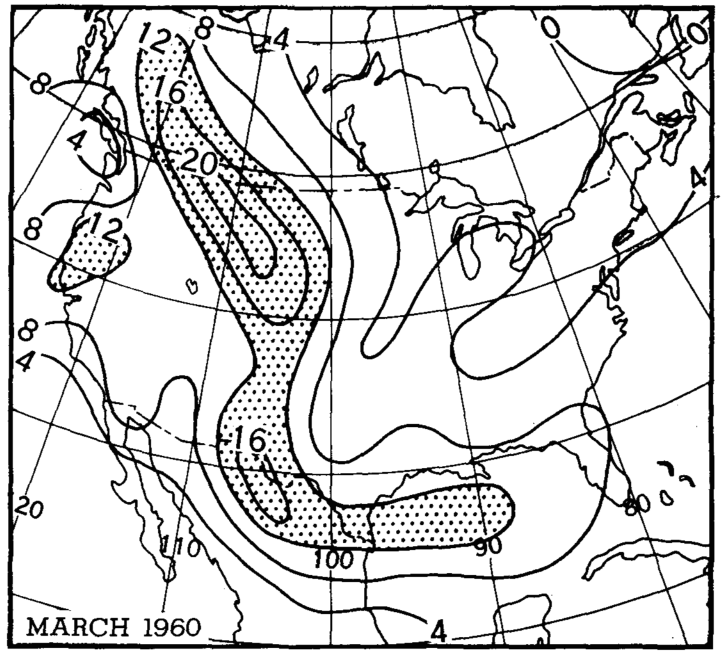

FIGURE 7.—Number of days in March 1960 with fronts of any type (within equal area quadrilaterals of 66,000 n. mi²). All frontal positions are taken from *Daily Weather Map,* 1:00 a.m. EST. Isoline interval is 4 days. Areas with 12 or more days with fronts are stippled Fronts were frequently located far south over the Gulf of Mexico.

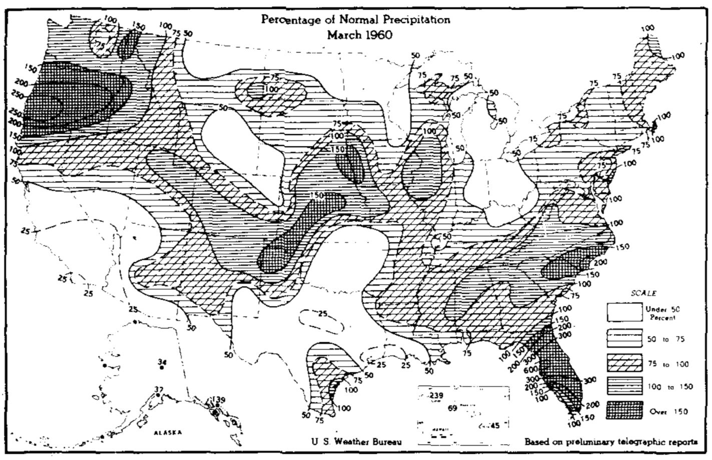

FIGURE 6.—Percentage of normal precipitation for March 1960. Precipitation was abnormally heavy in Oregon, Central Plains, and the Southeast. (From [13] April 11, 1960).

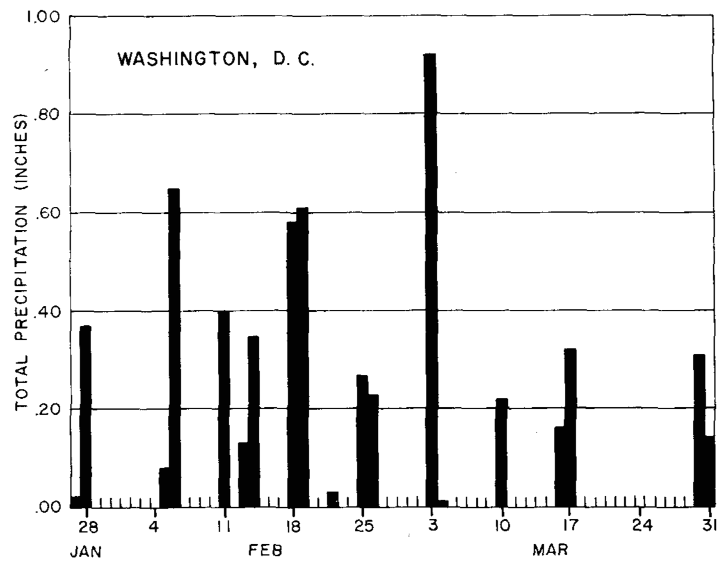

FIGURE 8.—Precipitation for 24-hour periods in inches at Washington, D.C., for February 27–March 31, 1960. Interesting 7-day periodicity existed from mid-February to mid-March.

Some old records were broken by a wide margin. For example, at Moline, Ill., the March mean temperature of 19.9° F. was 7.3° below the previous record made in 1912. Also, this March was the coldest month of the winter at Charleston, W. Va., Louisville, Ky., Harrisburg, Pa., and Dayton, Ohio.

The degree of unusualness of the cold weather may be derived from figure 10 which gives the geographical distribution of the standardized departure from normal of the monthly mean temperature. It was obtained for 130 stations, evenly distributed over the United States, by dividing the observed monthly mean temperature anomalies by their respective standard deviations, which have been computed by Thom [11]. The departures this March were more than 2 standard deviations over a large area of eastern United States, roughly corresponding to the region

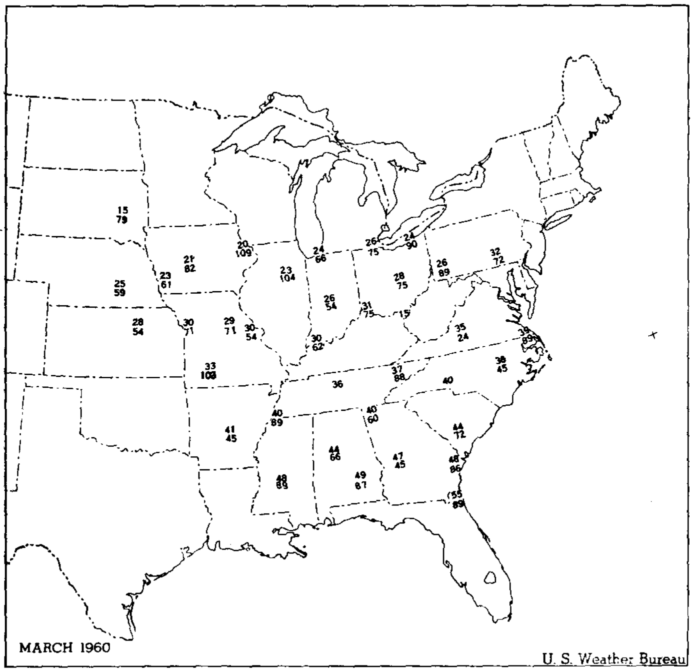

Figure 9.—Numbers above stations are mean temperatures (° F.) for March 1960 that were lowest on record for March. Numbers below stations are approximate period of record. These are not all the stations that reported records but were selected to indicate the extensive area of extreme cold.

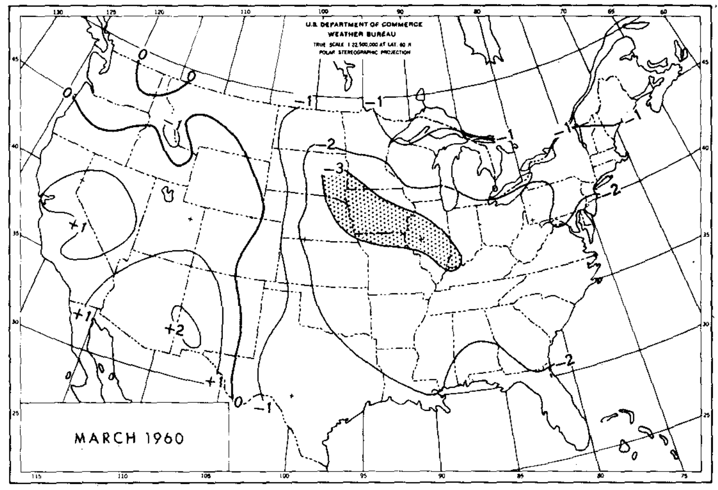

Figure 10.—Standardized departures from normal of monthly mean temperatures for March 1960. Average temperatures over a large area in eastern United States were more than 2 standard deviations below normal.

where record temperatures for March occurred, and greater than 3 standard deviations for a sizable region in central United States. With random sampling from a normally distributed population, the probability of obtaining a negative, standardized departure of 3 would be about 1 in 800.

The low monthly mean temperature in the East resulted from persistent extremes. The band of high frequency of fronts (fig. 7) outlines the periphery of the persistently cold area. Frontal systems seldom penetrated the cold air mass that lay over the eastern United States. During the first week most places were colder than normal except for small areas in extreme southwestern and northeastern United States. (See Chart A in No. 10 of [13].) Temperatures averaged more than 25° F. below normal in the northern Rocky Mountain and central Plains States. As the month progressed and ridging took place in the West, the relatively warm area initially confined to the Southwest migrated slowly northward and then spread eastward. In the East the weather in New England cooled markedly, as the 700-mb. trough off the east coast intensified.

For the week ending on March 27, temperatures averaged generally above normal west of the Plains States but were still below normal in the eastern half of the country. Near the end of March temperatures went to above normal over almost the entire United States as the blocking regime disappeared and strong westerlies and warm air spread across the country.

A further breakdown of the temperature records into shorter periods highlights the continuous nature of the cold weather. At Moline, Ill., Washington, D.C., Macon, Ga., and Shreveport, La., representative of the region of extreme cold, the daily maximum and minimum temperatures for March 1960 were plotted against time along with their normal values (fig. 11). During the first part of March both maximum and minimum temperatures remained below their respective normals. In fact, the maximum hovered close to the normal minimum. Many stations reported interesting cold weather phenomena indicating long duration of cold. For example, Atlanta, Ga., had freezing temperatures on 18 days, 7 more than the previous record; at Des Moines, Iowa, temperatures were 10° or more below normal for the first 26 days of March. At the two southern stations, Macon, Ga., and Shreveport, La., warming during the month was rather gradual but greater than the normal, for this time of year, so that by the last week of March, temperatures were near normal. At the northern stations, Moline, Ill., and Washington, D.C., temperatures remained cold until around March 25, 1960, when a pronounced warming set in and temperatures rose rapidly to above normal values. This occurred just after the marked change in circulation described earlier.

5. RELATIONSHIP BETWEEN TEMPERATURE AND CIRCULATION

The above normal ridge in the West and stronger than normal trough in the East fit the observed temperature distribution, but the Gulf of Alaska Low and absence of positive height anomalies in northwestern Canada do not generally favor cold weather in eastern United States [3, 5]. However, Rex [9] showed that in Europe and the Atlantic blocking is associated with cool weather south of the anticyclonic portion of the block. That a similar

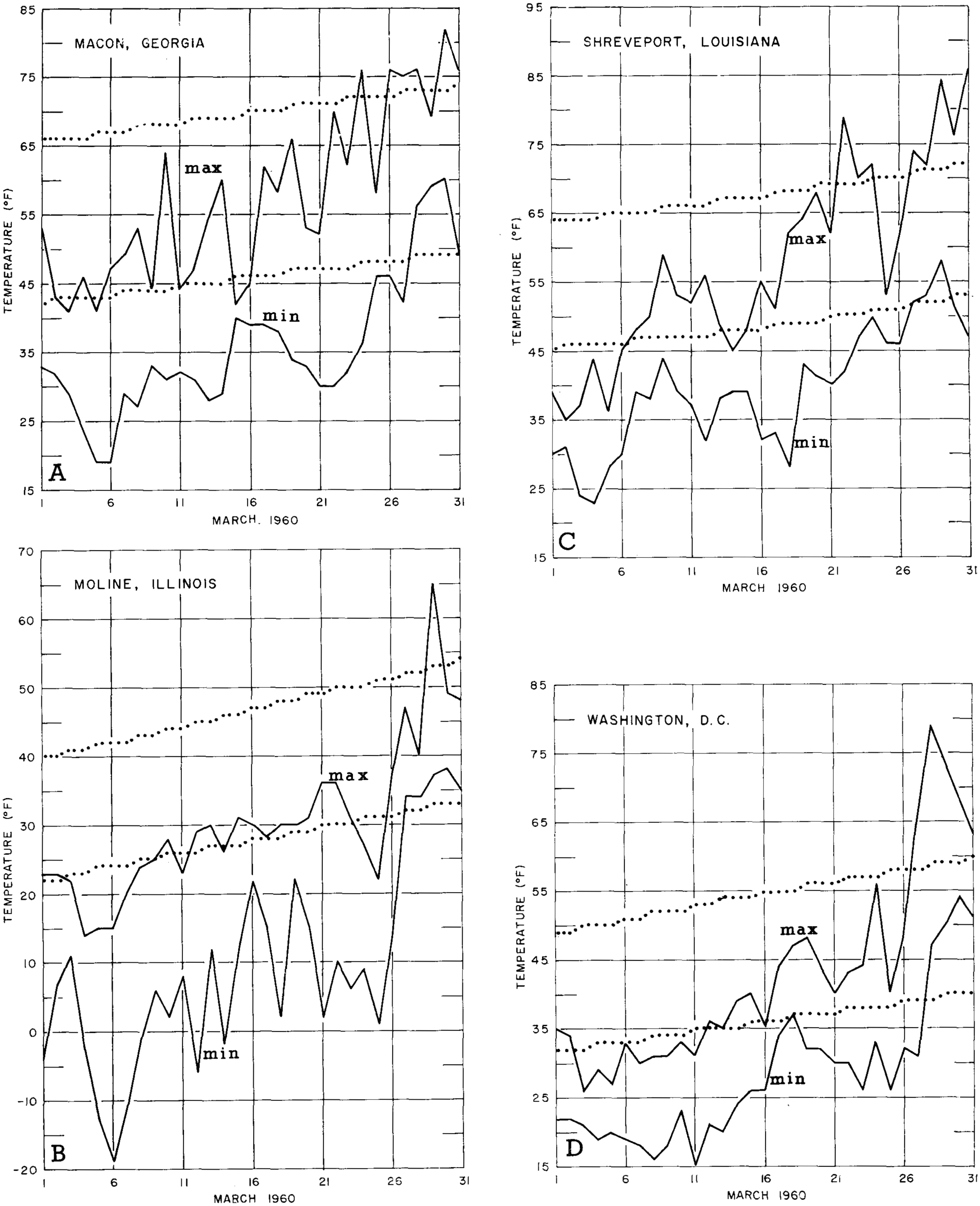

Figure 11.—Maximum and minimum surface temperatures (° F.), March normal dotted, March 1960, solid, for indicated cities in eastern United States. Remarkably persistent cold weather existed up to the final days of March.

TABLE 2.—*Snow cover (more than trace) at two stations for selected days in March. Column 3 shows number of years snow cover was present on date in column 2. Column 4 gives depth of snow on the ground on that date in March 1960.*

1 Station	2 Date in March	3 No. of years snow cover present	4 Snow depth March 1960 (in.)
Bismarck, N. Dak. (1943–59)	1	14	0
	10	14	5
	20	10	2
St. Louis, Mo. (1929–59)	1	2	3
	10	4	4
	20	0	10

relationship was operating this March in North America is illustrated in figure 5. Note that while the blocking was strong, temperatures in eastern United States, represented by Moline, Ill., and Washington, D.C., were cold and did not exceed the normal until after the blocking disappeared.

A factor which contributed to the cold temperatures in the United States was the abnormal cold of the air masses leaving the Canadian source region. Monthly mean surface temperatures and thicknesses (1000–700 mb.) averaged below normal everywhere in Canada except along the coasts. Temperatures for the month averaged up to 8° F. below normal and thicknesses 240 ft. below normal in the MacKenzie River Basin. From this area several migratory Arctic anticyclones moved into eastern United States. (See Chart IX in [12] and fig. 2.)

This factor, plus the circulation at 700 mb., although favorable for cool weather, hardly explain the record cold observed this March. It has been suggested by Namias [8] that an important part of the reason for the persistence of such extreme temperatures was the establishment, in the latter part of February, of an extensive and deep snow cover over areas where snow in not normally found at this time of year. He showed that observed temperature anomalies exceeded those normally expected from the observed 700-mb. mean circulation. The direct influence of the circulation on the temperature distribution was assessed objectively, although imperfectly, by using statistical equations developed by Klein et al. [3]. These equations, although designed for 5-day forecasting, were found to explain 63 percent of the temperature variability when applied to observed monthly mean 700-mb. height [3]. The objective temperatures derived in this manner from the observed 700-mb. mean for March 1960 were much too warm in eastern United States where observed temperatures were very cold (fig. 12). This appears to support the hypothesis that snow cover played an important role in keeping the polar outbreaks very cold as they progressed southward.

Charts prepared at the National Meteorological Center of the U.S. Weather Bureau showed that the southern boundary of the snow cover (1 inch or more) extended

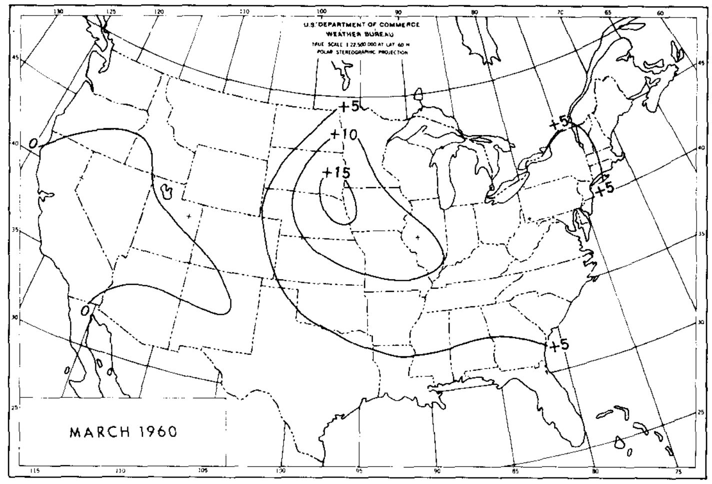

FIGURE 12.—Error (° F.) (forecast minus observed) in temperature specification which was made when statistical prediction equations described in [3] were applied to the observed 30-day mean 700-mb. heights for March 1960. Observed temperatures were much colder in central United States than those indicated by equations.

roughly on March 1, from southern New England to the Texas Panhandle, on March 10, from South Carolina to Colorado, and on March 20, from southern New England to Kansas.

At many stations with long periods of record daily values of the depth of snow on the ground are available, although homogeneous records are scarce. Nevertheless, the records at Bismarck, N. Dak. and St. Louis, Mo., were examined to help estimate the normal frequency of snow cover in and upstream from the area of extreme cold this March. The results are presented along with the snow cover for March 1960 in table 2. These data indicate that snow cover is quite common at Bismarck in March but rather rare at St. Louis. This, in conjunction with the U.S. Weather Bureau snow cover chart previously referred to, suggests that the southern boundary of snow cover extended farther south than normal this March. This factor could have contributed significantly to the excessively cold temperatures, especially in the southern areas.

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